Introduced Mammals in Victoria

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Introduction

Since the advent of white man in Australia, many species of mammals have been introduced into this country. Some of these species were brought in as domestic livestock for the supply and production of meat and wool, while other species were introduced for sport and recreation, as pets, and for the misguided endeavours of the Victorian Acclimatization Society. A few species such as rats and mice were introduced accidentally, presumably with infested ships cargo. Unfortunately, many of these species have been able to escape into our wilderness, farming and urban areas, and have successfully managed to breed and establish colonies in a wide range of habitats. In Victoria, about twenty species of introduced mammals are living in the wild, some of course more successfully than others (Table 1). Most of these have since been declared as pest or vermin animals.

Surprisingly, the release of exotic mammal species is still continuing. Two species of deer, the hog deer (*Axis porcinus*) and the fallow deer (*Dama dama*) have recently been released into Victorian forests and bushland for future sport. Unconfirmed reports to the Victorian Deer Advisory Council suggest the presence of yet another species, Japanese sika (*Cervus nippon*) in the Mallacoota area (Anderson 1978). At least four species of deer: hog, sambar, red and fallow are now roaming wild in large numbers in the Eastern Highlands where they may exert pressure on the already oppressed native fauna and flora by competing for food and shelter. In New South Wales' Royal National Park, culling of rusa has been necessary because of their high numbers (Anderson 1978). Because of damage done to vegetable crops by sambar deer in the Upper Yarra area, they were declared vermin in three Shires from 1951-61. Deer are also a potential host for various viral and bacterial diseases and can harbour helminth parasites and roundworms which are found in sheep

Table 1. Mammals introduced into Victoria, which are capable of living in the wild

-	*Rattus rattus*	Black rat, Ship rat
-	*R. norvegicus*	Brown rat, Norway rat
-	*Mus musculus*	House mouse
•	*Oryctolagus cuniculus*	Rabbit
•	*Lepus capensis*	Hare
•	*Canis familiaris*	Domestic dog
•	*Vulpes vulpes*	Fox
	Mustela putorius	Ferret
	Felis catus	Cat
	Equus caballus	Horse
•	*Sus scrofa*	Pig
+	*Dama dama*	Fallow deer
+	*Axis porcinus*	Hog deer
+	*Cervus unicolor*	Sambar
+	*C. elaphus*	Red deer
+	*C. timorensis*	Rusa
+	*Axis axis*	Chital
	Bos taurus	European cattle
	Capra hircus	Goat
	Ovis aries	Sheep

- = control is legislated under Health Act 1958
• = control is legislated under Vermin and Noxious Weeds Act 1958
+ = protected under Wildlife Act 1976.

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and cattle (Anderson 1978). Military-like hunting operations with four-wheel drive vehicles and packs of dogs are often even more destructive than the deer themselves. Whilst considerable effort is spent on the management and protection of deer for the benefit of only a smal section of the community, it is ironical that the native wombat (*Vombatus ursinus*), doing relatively little harm other than to rabbit fences, is still declared vermin. It has been suggested that goats may be used to control blackberry in timber crops. Will Australia eventually become an open zoo?

A number of the species in Table 1 are considered to be important in terms of economics, disease and wildlife conservation. Thus, feral dogs and cats, foxes, pigs and rabbits are treated separately and aspects of their distribution, breeding, diet and control are discussed below. However, mice, particularly in plaguc years, and rats in urban and farm areas, are also of economic and public health significance.

Any detailed studies on the effects of introduced species in wilderness areas would be extremely complex. In most situations, scientists are asked to "focus in" on one species at a time, and so wider interpretations of their specific findings can often be expressed only in general terms. It is important to realize that when attempts are made to assess the impact these exotic intruders make on our native fauna and flora, we give consideration to all factors that may affect the latter. This should include all introduced animals, plants and, of course, man. Thc disappearance or reduction in numbers of indigenous predators such as the thylacine (*Thylacinus cynocephalus*), the tiger quoll (*Dasyurus maculatus*) and the eastern quoll (*Dasyurus viverrinus*) have only added to our speculation regarding the impact that introduced predators may have exerted on them.

FOXES

General

The first introductions of the European red fox (*Vulpes vulpes* L.) to Australia took place in the 1860s and 1870s with most releases being near Melbourne (Rolls 1969). The main purpose of the releases was to provide sport for "Colonial Gentlemen" and there was generally little thought as to the possible harmful effects of fox introduction. The subsequent spread of the species was rapid. Foxes are able to survive and indeed flourish in a large variety of habitats ranging from rain forest to semi-desert but it would seem that they prefer to live in areas disturbed by man. Studies in America and Europe indicate that a family of foxes establishes a home range of about 5-7 square kilometres. The territorial boundaries are generally well established and often conform to natural physical boundaries such as roads, streams and lake shores.

Distribution

Foxes range over some two-thirds of the continent, their northern limit being within 100 miles of the Gulf of Carpentaria. In Victoria, the density of foxes appears to be greater in closely settled agricultural areas and this is undoubtedly linked to food supply. Even large towns and cities support a resident fox population.

Breeding

Vixen are mono-estrus and are receptive to the male fox for only a few weeks of the year. In Australia adult males are probably infertile from September to March of the following year. Both vixen and male foxes are sexually mature at ten months of age and according to overseas work, nearly all healthy vixen produce a litter every year. In Australia, only few adult vixen are barren. This, combined with an average litter size of 4-5 viable young, accounts for the very high rate of reproduction amongst foxes in the field. According to overseas studies, the gestation period is usually 51-52 days.

The young are born and reared in a den, which is usually an enlarged rabbit burrow. However stone heaps, hollow logs and natural caverns are frequently utilized as breeding sites. The vixen establishes the den site and may scratch out several dens. The young often utilize two or three dens in a confined area.

Weaning takes place after the first month or so and the young may frequent the natal den (or neighbouring dens) for several months thereafter. Dispersion usually takes place in late summer or early autumn. The sex ratio in Victoria and New South Wales shows a preponderance of males over females (Coman 1973a; Croft and Hone 1978).

Diet

Extensive investigations on the diet of foxes in Victoria indicate that the fox is an opportunist predator and scavenger, consuming an extremely wide variety of foods. The importance of any particular food item in the diet is heavily dependent on the relative availability of that food. Hence, there are marked differences in the diet of foxes from various habitat types and seasonal changes in diet are quite evident. In areas of agricultural or pastoral land, rabbits, house mice and sheep are the most important mammalian foods eaten. However, in heavy forest areas, largely undisturbed by man, native mammals are consumed in large quantities and they appear to compensate for the lack of rabbit, sheep and house mice in these situations (Coman 1973a; Brunner *et al.* 1975, 1976, 1977).

The seasonal variation in incidence of various food items is marked. During summer, large numbers of insects and fruits (particularly blackberries) are eaten. At times, insects or wild fruits account for the bulk of the fox's dietary intake. Nevertheless, the fox is primarily a carnivore preying on smaller mammals and feeding on carcasses of larger ones.

Disease

In Australia, we are fortunate that our fox population is probably not involved in the spread or persistence of any disease which has a major economic or public health significance. Nevertheless, foxes harbour a wide range of viral, bacterial, protozoan, helminth and arthropod organisms which may or may not exert some pathogenic affect upon their host.

Distemper, hepatitis and mange appear to be the major disease conditions in Australian foxes, although there is no documented evidence of the effects of these diseases on the fox population. Disease outbreaks appear to be sporadic and follow no definite pattern. However, there is some presumptive evidence that serious disease outbreaks amongst foxes occur only when the fox population in a particular area is high. The helminth parasites of foxes in Australia have been investigated in detail and at least four species of tapeworms and six species of roundworms are known to parasitize the animals (Coman 1973b).

We are fortunate that the fox in Australia does not act as a carrier for the hydatid tapeworm, *Echinococcus granulosus*. In some other parts of the world, foxes are important hosts for this parasite.

Foxes harbour a number of external parasites, the most important of which are the mange mites. Species of fleas, lice and possibly ticks also occur on foxes. The viral and bacterial diseases of foxes have been poorly studied, but leptospirosis and toxoplasmosis are known to occur in foxes.

Economic damage

Although foxes have often been considered responsible for heavy losses in lambs, there is little evidence to support this. Investigations indicate that, although large amounts of sheep material may be eaten, most of this is in the form of carrion. Lamb mortality studies suggest that the fox has probably been over-rated as a predator of viable lambs (McFarlane 1964). Despite this, one cannot deny that individual farmers sometimes suffer heavy lamb losses because of the activities of individual "rogue" foxes.

A bounty payment system which was introduced in Victoria in 1949 has now been revoked. The payment per scalp was 75c and in 1977 a peak annual return of over 100,000 scalps was achieved. The current value of fox skins compensates hunters well for their efforts.

Environmental aspects

The Victorian studies on fox diet indicate that substantial predation upon indigenous fauna occurs in areas of heavy forest or scrub. It is commonly

believed that this poses a serious threat to the existence of many of our smaller indigenous fauna species. However, as foxes have become dependent on small native mammals in these areas as their staple food, it should be remembered that, after more than a century of this predator-prey relationship, there appears to be still an abundance of most of the small indigenous fauna species throughout these areas. The disappearance of certain prey species in more vulnerable areas such as small and isolated reserves or in desert lands, is possibly the result of additional pressure on those species by cats, dogs and by man. Nevertheless, the wisest policy is to take the view that fox predation on indigenous fauna is undesirable and should be minimized.

Foxes with mange could spread this disease to wombats and if rabies came to Australia, foxes would most likely be the principal agent in the spread of this disease to mammals, including man. In late summer foxes eat large quantities of blackberries. The seeds in the droppings germinate readily and so the fox assists in the spread of this weed (Brunner *et al.* 1976).

Control

A variety of means have been used to control foxes in Victoria. These include poisoning, daylight drives, fumigation of dens and night spotlighting. The most efficient technique is probably that of poisoning, as foxes are extremely susceptible to 1080 poison. Fumigation of dens with chloropicrin or similar products is a useful control measure in summer, when juveniles and vixen are still in the dens. It is probably unwise to destroy established dens by digging or explosives, since the foxes will then establish new den sites in other areas. It is better to have the animals using the same known dens year after year and to fumigate these every breeding season when signs of activity are obvious.

Night spotlighting is often employed in fox control, particularly during lambing time, when control of individual "killer" foxes is desired.

DINGOES AND FERAL DOGS

General

The dingo (*Canis familiaris dingo* Blumenbach, 1780) is generally considered to be a native mammal, although it may have been in the country for only some 10,000 years or so. The origin is unknown but it is thought to be in the ancestral line from primitive dog to present domestic dog. Indeed, it is very difficult to separate dingoes from ordinary domestic dogs on the basis of blood tests, skull measurements etc. Many people use the coat colour of the animal as a means of discrimination, but black and tan as well as yellow dingoes may be recognized.

Feral domestic dogs (*Canis familiaris familiaris*) or hybrid animals resulting from inter-breeding with dingoes are a more recent addition to our bushland. They undoubtedly originated from straying farm dogs in the early days of settlement. Domestic dogs and dingoes inter-breed freely so that we now have dingoes, cross-breeds and feral domestic dogs roaming the bush.

Distribution

Dingoes and feral dogs are in all States except Tasmania but are of most concern in the more arid pastoral zones of Western Australia, South Australia, Northern Territory and Queensland as well as the heavily forested Eastern Ranges of New South Wales and Victoria. They are usually in areas remote from human habitation and are by nature rather shy animals. In Victoria they are found throughout the Great Divide from the New South Wales border to the area about Healesville and Marysville. They are also in extensive areas of the more rugged country in the north-east of the State. Dingoes may still be present in the north-west of the State (Little Desert — Big Desert) and an animal assumed to be a dingo was killed near Natimuk recently. However, reports from the north-west region are few.

Dingoes are not found in the wild outside Australia but recently dog fanciers in other countries have shown great interest in breeding the dingo as a "show" dog.

Breeding

Dingoes differ from feral dogs in that they breed only once a year. Domestic dogs can breed at least three times in two years.

Dingoes mate between April and June and have their young between June and August. Like domestic dogs, the gestation period is about 63 days. Not all bitches breed in their first year and this is often taken to indicate social subordination of these younger animals by older animals. Males have an annual sexual cycle and very few sperm are produced in summer.

The dingo bitch produces an average of five pups usually in places such as large hollow logs, natural caverns etc. According to some recent research work, there is evidence to suggest that not only parents, but also non-breeding young animals (first year) help rear the young (Newsome *et al.* 1973).

Diet

Dingoes and feral dogs eat a great variety of food, ranging from large native mammals through to insects, fruits and herbs. The introduction of livestock and rabbits to Australia has extended their range of food items. The results of a dietary study of Victorian dingoes and feral dogs are shown in Table 2. On a volume basis, wallabies and wombats are the major food items. It can be seen from the Table that sheep and cattle form only a small part of the diet. Nevertheless, it must be remembered that individual dogs can cause heavy stock losses from time to time (Coman 1972a). In Western Australia the most common food for dingoes was found to be the red kangaroo (*Macropus rufus*) and the common wallaroo (*M. robustus*) (Whitehouse 1977). In Central Australia the major items in their diet are the rabbit, the long-haired rat (*Rattus villosissimus*), the house mouse (*Mus musculus*), the spinifex hopping-mouse (*Notomys alexis*) as well as lizards and birds (Newsome *et al.* 1973).

Parasites and diseases

The most important parasite of dingoes and feral dogs in south-east Australia is, undoubtedly, the hydatid tapeworm. This worm is probably present in 80-90% of these dogs, but is very rare in domestic farm dogs in the same areas. The hydatid worm is important because its intermediate stage (hydatid cyst) is found in man, domestic animals and native animals. The disease in man can be fatal and it may well kill some native mammals. Recent Victorian research has shown that the high incidence of hydatid worms in dingoes and feral dogs is probably due to the fact that dogs eat large numbers of infected wallabies (i.e. wallabies with hydatid cysts) (Coman 1972b). This is a self-perpetuating cycle, the wallabies picking up hydatid eggs from grass and herbage around dog faeces. Man can become infected by handling dingoes or feral dogs and strict hygiene should be practised. In addition to hydatid tapeworms,

Table 2. Food items in stomach contents of 166 dingoes and feral dogs in Victoria (Coman 1972)

Food items	Percentage occurrence in diet
MAMMALS	
Wallaby (*Wallabia bicolor*)	23
Wombat (*Vombatus ursinus*)	20
Eastern grey kangaroo (*Macropus giganteus*)	7
Possum (chiefly *Trichosurus vulpecula*)	7
Echidna (*Tachyglossus aculeatus*)	6
Rabbit (*Oryctolagus cuniculus*)	6
Sheep (*Ovis aries*)	4
Cattle (*Bos taurus*)	3
BIRDS	5
REPTILES	6
INSECTS	33
HERBAGE	85

dingoes and feral dogs harbour a number of other helminth parasites such as the sheep and cattle bladderworm (a tapeworm of dogs of which the intermediate stage is seen as large watery bladders attached to the gut of sheep and cattle) and also roundworms and hookworms (Coman 1972a).

Dogs can also become infected with mange, distemper, hepatitis and a variety of other diseases, and if rabies came to Australia, dogs could be important carriers. Generally the animals seem to have little influence in the spread of important livestock diseases. The possible exception to this could be hydatid disease.

Economic importance

Despite a huge amount of folklore and over 150 years of control work, we still have little idea of the real damage caused by dingoes and feral dogs. There can be no doubt that severe losses of livestock occur from time to time. A recent survey shows that livestock predation in Victoria is confined almost entirely to sheep flocks (Stevens and Coman unpublished data).

Control of dogs itself is a fairly expensive operation. Each year the Victorian Department of Crown Lands and Survey alone spends some $300,000 on dog control.

Aerial poisoning of dogs has not been carried out in Victoria for a number of years as it is considered to be relatively non-specific. Also the success of such poisoning is difficult to measure. It is unlikely that aerial poisoning of dogs will be considered in the future.

Ground poisoning of dogs, using carefully prepared poison doses and well placed baits appears to be more promising. Dogs are extremely susceptible to 1080 poison and, using this fact, it may be possible to produce a bait which is effective on dogs but less dangerous to desired wildlife species (Rathore 1980). Combining this selectivity with carefully placed baits could very well result in the control of many dogs with a minimum risk to other animals. However, it appears that not all dogs will take baits and, therefore, poisoning cannot completely replace trapping.

FERAL CATS

General

A feral cat is best defined as a cat (*Felis catus* L.) which obtains its own food by hunting and scavenging. Feral cats may live in close proximity to human habitation or may be completely isolated in the bush. Since cats kept as pets also roam and hunt, a precise distinction between feral and straying animals can sometimes prove difficult.

The cat was first domesticated in Egypt about 3,500 years ago and now has a world-wide distribution. It is probably true that most countries having domesticated cats also have a feral population.

Despite a pronounced coat colour polymorphism, cats show little variation in size and average females weigh 2.3 — 3.0 kg and average males 3.5 — 6.0 kg. There is no sound evidence to suggest that the average feral cat is larger than the average cat kept as a pet. They are both the same species (Scott 1972; Jones and Coman personal communication).

Distribution

Feral cats occur in all habitats in Australia (Anon. 1977; Bolton and Latz 1978; Marshall 1966). They are found in the Gibson Desert, the Kimberleys and Cape York Peninsula and even on subantarctic Macquarie Island. In the more densely settled areas feral cats appear to be concentrated about garbage dumps, picnic sites and camping grounds. The density of cats in various parts of Australia is unknown but at Macquarie Island densities may reach up to seven cats per square kilometre (Jones 1977).

Breeding

Female cats may have from 1 to 8 kittens per litter, but the usual litter size is from 3-5. Gestation lasts for 65 days and kittens are born between spring and late summer. Each breeding cycle takes a minimum of 4½ months and one female may produce two litters per year. Kittens weigh an average of 100g at birth and are weaned after six weeks. Preliminary observations suggest that litters are born and raised in rabbit burrows, rock piles and, possibly, hollow logs. In all other

respects, breeding of feral cats is likely to be the same as breeding in domestic cats.

Diet

Research in Victoria suggests that feral cats will eat a wide variety of food and their prey at any time of the year consists largely of those species which are most abundant and easily caught (Coman and Brunner 1972). Mammals (particularly rodents and lagomorphs), birds, reptiles, amphibians, fish, insects, carrion, human garbage and plant material are all eaten. In areas of high rabbit density, rabbits are by far the most important food item. Similar results have been obtained in a more recent dietary study on feral cats (Jones and Coman personal communication). Usually cats hunt at night and peak activity is thought to be at evening or early morning. The diet of feral cats in Victoria varies markedly depending on the habitat. The results of a dietary survey carried out in 1969-70 in agricultural and forest areas are summarized in Table 3 (Coman and Brunner 1972).

The greater reliance on native mammals in heavy forest is, no doubt, linked to the fact that such animals are usually more common in bush areas whilst mice and rabbits are less common.

Disease

Probably the most important disease transmitted to man and to domestic and free living animals by cats is toxoplasmosis (*Toxoplasma gondii*). It can lead to serious foetal damage (rare in humans) if the mother is infected during pregnancy. It is also a fairly serious disease of livestock especially sheep in New Zealand and Tasmania and it must be assumed that feral cats play some part in its transmission.

A wide range of native animals have been found to be infected with toxo-

Table 3. Food items of 80 feral cats in Victoria expressed both as percentage by volume and as percentage occurrence

Food item	Agricultrual and pastoral land		Heavy forest	
	Volume	Occurrence	Volume	Occurrence
MAMMALS	91.5	81.5	85.7	60.6
Introduced spp.				
Oryctolagus cuniculus	62.0	29.6	20.5	11.3
Mus musculus	27.0	40.7	11.8	7.5
Ovis aries	1.5	3.7	0.0	0.0
Native spp.				
Pseudocheirus peregrinus	0.0	0.0	11.4	5.7
Trichosurus vulpecula and *Trichosurus caninus*	0.0	0.0	6.6	7.6
Rattus fuscipes	0.0	0.0	6.6	8.7
Rattus lutreolus	0.0	0.0	6.8	4.6
Macropus spp.	0.0	0.0	9.7	1.9
Schoinobates volans	0.0	0.0	4.0	1.9
Antechinus spp.	0.0	0.0	0.8	1.9
Sminthopsis spp.	0.0	0.0	0.3	1.9
Perameles nasuta	0.0	0.0	T	1.9
Unidentified	3.0	14.8	7.3	5.7
VEGETABLE MATTER	T	25.9	2.5	52.8
INSECTS	T	14.8	0.8	15.1
BIRDS	T	11.1	5.8	5.7
LIZARDS	T	3.7	1.1	1.9
FROGS	1.0	7.4	0.0	0.0
OTHER ITEMS	6.0	29.6	3.5	26.4
CAT FUR	3.0	14.8	0.2	20.7
HOUSEHOLD SCRAPS	0.0	0.0	3.7	5.7

T = trace

plasmosis. The original spread of this disease is commonly linked with the presence of feral cats. The sexual stage of *T. gondii* can only mature in members of the cat family and the infective oocysts are shed in their faeces (Butler 1979). Subsequently, these oocysts are picked up by grazing animals. This disease, found in sheep and other domestic animals, has also been found in several species of macropods, rodents, bandicoots, possums, dasyurids and in wombats, rabbits and birds (Attwood *et al.* 1975; Gibb *et al.* 1966; Munday 1972, 1978).

The disease can kill infected animals when they are under stress, such as when food is in short supply (Arundel personal communication).

Sparganosis is a disease caused by the larval stage of a tapeworm which is commonly found in feral cats. The intermediate stage of the parasite, called the sparganum, is very common in wild pigs and is also frequently encountered in smaller native animals. Man can get this disease but it is uncommon.

If rabies ever came to Australia, the feral cat could act as a carrier but dog and fox would probably be more important in this regard.

Economic damage

Besides the transmission of various diseases, feral cats appear to cause little or no economic damage in the agricultural situation.

Environmental aspects

It is generally known that feral cats prey heavily on small indigenous mammals and birds in wildlife habitats. It is possible that feral cats may exert a detrimental effect on other small carnivores such as the tiger quoll, eastern quoll and the brush-tailed phascogale (*Phascogale tapoatafa*) by direct competition for food. Certainly, the range and number of some of our smaller indigenous carnivores has decreased markedly since the advent of white man. The impact of predation by cats is difficult to assess, particularly in complex wilderness areas where foxes and feral dogs pose a similar threat. In a relatively simple ecological system on Macquarie Island, cats caused the local extinction of a ground nesting parakeet and it has been computed that the Macquarie Island cat population eats in excess of 50,000 birds per annum (Jones 1977). In areas containing endangered mammal or bird species every effort should be made to eradicate feral cats or limit their numbers.

Control

Although feral cats are not declared vermin under the Vermin and Noxious Weeds Act 1958, they are widely regarded as a pest animal and in some situations such as National Parks and Wildlife Reserves, active control has been attempted. Usually cage trapping has been used, but little research has been done on the effectiveness of this technique. At the moment various trap types and trapping methods are being evaluated.

Cats may be poisoned using 1080 meat baits, but there are probably some hazards to other carnivores. In dense bush areas some success has been achieved by suspending small baits some 500 mm above the ground where raptores and small carnivores have less access.

Like foxes, cats may be killed by shooting in conjunction with night spotlighting. The eyes shine very brightly at night and since the animals are mainly nocturnal in habit this technique can be used with some success.

THE EUROPEAN RABBIT

General

Attempts were made to establish rabbits (*Oryctolagus cuniculus* L.) in Australia right from the commencement of European settlement. Five domestic rabbits were listed amongst the livestock brought by the First Fleet in 1788 (Stead 1935). Rabbits were mentioned in early reports from Fawkner's settlement on the Yarra River at Port Phillip (Rolls 1969). Rabbits were also released on several islands around the Victorian coastline to provide food for shipwrecked sailors (Stokes 1846). The Henty family brought rabbits from Tasmania to Portland, in western

Victoria (Bassett 1954), long before the more well-known episode which followed.

In 1859 about twenty-four wild and domestic rabbits were brought to Melbourne from England and established at "Barwon Park", the property of Thomas Austin, near Winchelsea. Although the details are uncertain, it is clear that these rabbits became established very well indeed.

Of all our introduced mammals, the rabbit has probably had the greatest ecological impact in Australia.

Distribution

Rabbits are found virtually throughout the Australian mainland south of the tropic of Capricorn, in Tasmania and on numerous coastal islands.

Isolated colonies of unknown status occur further north in Western Australia, the Northern Territory and Queensland. Rabbits are found in a wide range of environments including arid stony deserts, sub-alpine valleys, sub-tropical grasslands, wet coastal plains and a wide variety of Mediterranean-type habitats. In Victoria, they occur in habitats associated with nearly all types of land use including areas reserved for conservation purposes.

Breeding

The gestation period is about 28-30 days and mating can occur immediately after parturition.

The kittens are born blind, without fur and in a nest which the doe prepares in a burrow. Young kittens first emerge at an age of about 15-20 days.

Females become sexually mature at about four months of age and males at about five months.

The following generalizations concerning rabbit reproduction are drawn from data collected by the C.S.I.R.O. Division of Wildlife Research from five environments (Myers 1970).

The shortest and most sharply defined breeding season occurs in the sub-alpine region where reproduction is limited to the late spring and early summer months. In Mediterranean-type climates, however, reproduction occurs in most months of the year with a prominent peak in spring.

The average productivity of young per female per year ranged from 13.1 (sub-alpine N.S.W.) to 29.4 (Mediterranean N.S.W.) and the mean numbers per litter (in embyro stage) ranged from 4.49 (arid N.S.W.) to 5.65 (Mediterranean N.S.W.).

In summary, the population in the Mediterranean habitat exhibited a markedly higher capacity for increase — almost twice that of the next highest site (sub-tropical Queensland) and approximately eighteen times that of the lowest site (sub-alpine N.S.W.).

Food and feeding

Rabbits are more selective than sheep in their grazing habits (Myers and Poole 1963; Farrington and Mitchell 1971). Their natural choice is for soft, green grass but when this becomes unavailable they choose food which is easily eaten and masticated, avoiding plants with disagreeable aromatic odours and tastes. In most instances such feeding coincides with a high protein intake. In drought conditions their diet becomes protein and energy deficient and this imposes a considerable stress on the animals.

Diseases

Diseases in wild rabbits are no direct threat to humans. Dogs, however, can become infected with the helminth parasites *Taenia pisiformis* and *Taenia serialis* by eating infected rabbits (Coman 1972a). The cysts of the latter parasite in rabbits are often mistakenly identified as hydatid cysts (Davies and Nicholas 1977). Hydatids has not been reliably recorded in rabbits in Australia.

Occasionally ectoparasites of rabbits are capable of transmitting microbial pathogens to man. The associated diseases include mange, scabies, dermatitis and plague (Yunker 1964; Pegg 1970).

The most famous disease associated with rabbits is the viral disease myxomatosis. Beginning from an experimental site near Corowa in 1950, a spectacular epizootic decimated rabbit populations and for the first time brought rabbits under control (Ratcliffe *et al.* 1952; Brereton 1953). It is expected

that myxomatosis will continue as a moderately severe disease of rabbits for some time to come (Edmonds 1972).

Economic damage

Although generally acknowledged, the economic damage caused by rabbits has not been well documented. However, the real extent of earlier losses was clearly revealed by the enormous increase in wool and meat production which followed the suppression of rabbits by myxomatosis (Reid 1953).

Even though the rabbit problem has been greatly reduced, the resources still required for control demonstrate the continuing economic impact of this species.

Some commercial benefit is derived from the sale of carcasses and skins of wild rabbits, but the commercial production of domestic rabbits is still not permitted in Victoria.

Environmental damage

The impact of rabbits on the Australian environment could well be described as disastrous.

Rabbits have significantly altered the botanical composition of extensive areas of natural habitat. This is mainly because they feed on certain species of plants at critical stages of development such as seeding and seedling establishment (Myers and Poole 1963). These findings have been supported and extended by subsequent studies (Cochrane and McDonald 1966; Churchill 1972).

Because of these ecological changes associated with high population numbers, rabbits have been blamed for the disappearance of the greater bilby, *Macrotis lagotis*, and the pig-footed bandicoot, *Chaeropus ecaudatus*, and for putting many other species under stress. Studies have shown that rabbits have had a drastic effect on the ecology of islands and that significant regeneration of the original vegetation can occur after the removal of rabbits (Norman 1967, 1970).

A further concern is the severe soil erosion which has occurred due largely to the grazing and burrowing activities of rabbits.

The control of rabbits in natural areas without undue disturbance of native flora and fauna presents a major challenge to those who manage land for conservation purposes.

Control

It was not long after the initial rapid spread of rabbits that their threat as a pest species became obvious. By 1869 it had been suggested that rabbit control be made compulsory in Victoria, and in 1880 the Rabbit Suppression Act was drawn up (Rolls 1969).

Today, the main methods of rabbit control are poisoning, fumigation, warren-ripping, harbour destruction, night shooting and exclusion fencing. Biological control through myxomatosis continues to be of great assistance (Edmonds 1972; Tighe *et al.* 1977; Shepherd *et al.* 1978). In recent years the European rabbit flea (*Spilopsyllus cuniculi* Dale) has been introduced as an additional vector of the myxoma virus (Shepherd and Edmonds 1976, 1979).

Advice on the most suitable methods of control in particular situations is readily available from local Inspectors of Lands throughout Victoria and from the Keith Turnbull Research Institute at Frankston.

FERAL PIGS

General

Feral pigs (*Sus scrofa*) in Australia are derived from domestic stock and they have established populations of high density in a wide range of habitats, chiefly in New South Wales, Queensland and the Northern Territory. Some feral pig colonies were established prior to 1870 but most are more recent in origin.

Feral pigs are a declared pest species in Victoria, New South Wales, Western Australia and Queensland. Elsewhere in Australia there is no legislation on feral pigs.

Distribution

Although feral pigs can be found in all States, they are of major significance only in New South Wales, Queensland and the Northern Territory. In New South Wales the greatest density of pigs

is located on the north-western river systems, flood plains and marshes. Populations of up to eighty pigs per square kilometer have been recorded (O'Grady and Hone personal communication).

High population densities also occur in large areas of Queensland but there is no detailed information on distribution.

In the Northern Territory, feral pigs are found only in the north of the State. There, the distribution of pigs is mainly restricted to the river systems.

In Victoria, two main population groupings can be recognized. The majority of animals are found in flood country adjacent to the Murray River in northern Victoria. The other main habitat is in the Eastern Ranges. Smaller colonies are also found is confined situations throughout the remainder of the State.

Breeding

The breeding season of feral pigs in Australia is generally unrestricted.

Sows begins breeding between 6 and 8 months of age if their live-weight exceeds 30 kg. The mean number per litter at birth is 6.5 and the mean number weaned varies from 0 — 4.5 depending on seasonal conditions. Two litters can be weaned in 12-14 months.

Populations of pigs studied in New South Wales have a potential rate of increase of about 300% per annum if resources are not severely limiting. This figure allows for normal hunting pressures.

Food and Feeding

Feral pigs have definite food preferences. Succulent green vegetation forms the bulk of the diet but if this becomes unavailable they become increasingly dependent on plant roots and animal material. Grain crops are particularly attractive even when there is an abundance of green vegetation. The animal tends to be nocturnal particularly during hot weather or when the population is disturbed.

Like domestic pigs, the feral pig has a poor tolerance of high temperature and when temperatures exceed 30°C it must drink water daily.

Disease

The major importance of feral pigs is their potential as a reservoir of exotic diseases particularly foot and mouth disease, swine fever, rinderpest, and trichinosis. This importance is compounded when the distribution of feral pigs is considered, particularly in northern Australia near possible points of entry of diseases from Asia.

Economic damage

Feral pigs cause losses in the pastoral industry and in grain and sugar production. In the pastoral industry the main pig problem occurs during the lambing season particularly in north-western New South Wales. Moule (1954) and Plant *et al.* (1978) have attributed fairly heavy lamb losses in particular flocks in Queensland and New South Wales to feral pig predation. In the investigation by Plant *et al.* (1977), it was estimated that in one season a total of over 600 lambs was killed by feral pigs from 1,422 lambing ewes. Pigs also ruin pastures by grazing and rooting, they break down fences and cause damage to water installations and bore drains.

Pigs have a significant effect on grain production in New South Wales and Queensland. In Victoria crop damage occurs to a lesser extent. Individual farmers may suffer heavy losses from time to time. Losses result not only from consumption of grain and foliage but also because areas of crops are destroyed by trampling. Losses in sugar production are mainly reported from northern Queensland.

Environmental aspects

There is little information available on the effects of feral pigs on the natural environment. Pigs living in forests and swamps can cause considerable damage rooting and wallowing and by spoiling water. There may be a significant effect on ground nesting birds because of damage to nesting sites and habitat. Although studies of pig food habits have not yet indicated predation on wildfowl or eggs, such damage may occur (Giles personal communication). In the high plains of Kosciusko, pigs feed

extensively on tuberous plants and this may cause damage to individual species and plant communities. Furthermore, these disturbances are usually followed by an invasion of weedy exotic plants (Wimbush personal communication). Pigs preying on lambs are likely to prey also on native animals for food. Tufts of hair of possum, koala and kangaroo have been found in droppings of pigs. It is likely that pigs pose a serious ecological problem in many areas and there is a definite need to investigate this possibility.

Control

Useful methods of control are trapping, poisoning and shooting.

Traps are simply small yards constructed of weld-mesh supported by steel fencing posts. Bait is used to attract the pigs into the traps and various devices are used to prevent the pigs from escaping.

For poisoning, pellets or grain are used as bait material. Meat bait injected with poison is also effective.

Shooting is best applied where small populations are restricted to certain watering points or as an ancillary to trapping and poisoning.

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